

ANNUAL PROGRESS SUMMARY
Project period January 1, 2003 – December 31, 2003

TITLE: THE QUATERNARY GEOLOGIC FRAMEWORK FOR THE CITY
OF SEATTLE AND THE SEATTLE-TACOMA URBAN CORRIDOR

Cooperative Agreement Number: 01HQAG0017

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ABSTRACT

Our investigations during this project year represent the continuation and development of a wide range of tasks that focus on the Quaternary framework of the Seattle area. Major accomplishments and expansion of scope this year include multiple 7.5-minute geologic maps into or through the USGS technical review process, completion of data acquisition and field work throughout the City of Seattle, continued progress on 3-D digital map products for Seattle, and free public Internet access of our entire geologic database, currently numbering over 55,000 exploration sites. Our emphasis on Quaternary geologic data is critical for any geologic or seismic-hazard studies because most of the central Puget Lowland has a recent sedimentary cover one hundred to over one thousand meters thick.

During this project year, we accomplished the following tasks:

- Completed USGS technical review (through Team approval) of five MF-series 7.5-minute maps at 1:24,000 scale in the Seattle-Tacoma area, plus a 1:100,000-scale compilation of King County geology;
- Completed USGS technical review of surficial geologic maps of the Seattle SW and NW quadrangles at 1:12,000 scale and near-completion of surficial geologic maps for the balance of the City of Seattle;
- Continued population of a database of existing subsurface geologic and geotechnical data, with an additional 15,000 individual records (points) of subsurface geologic information (now 55,000 total);
- Multiple abstracts, two book chapters, and several journal manuscripts and fieldtrip guidebooks;
- Response to requests for information from USGS scientists within and outside of the Earthquake Program, other Federal agencies, local governments, private consultants, and the public.
- Short courses, field trips, technical presentations, and public presentations, involving two of the largest planned capital projects in the region (Brightwater wastewater treatment plant and the Seattle Monorail Project); and

— three-fold leveraging of USGS NEHRP funds for 2003 that has expanded both the data collection and the geographic scope of the project.

BACKGROUND

Our investigations during this fifth year of the project represent the continuation and development of a wide range of tasks that focus on the Quaternary framework of the Seattle area. We have defined five major components to develop this framework and to disseminate the resulting information:

1. Develop the regional stratigraphy and chronology for the central Puget Lowland;
2. Create a subsurface geologic database for the City;
3. Prepare new surficial geologic maps of the City;
4. Develop the geologic model (3-D map and database) of the City; and
5. Provide education and technical outreach.

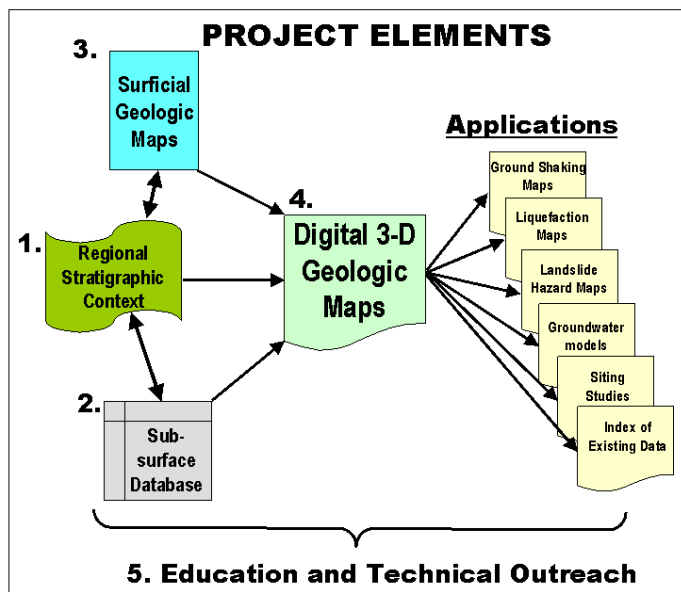


Figure 1: Elements of the Seattle Geologic Mapping Project

The surficial and 3-D geologic mapping in the four quadrants of the City of Seattle (Figure 2) provides the framework for the overall project. They are anticipated to be completed on a roughly annual cycle, with the first and second (Seattle SW and Seattle NW) through technical review as a USGS map publication. The sequence of map products is as follows (3-D maps are anticipated to lag their surficial counterparts by two calendar years):

MAP QUADRANT	SURFICIAL GEOLOGIC MAP
Seattle SW	2001 (in press, USGS WPG)
Seattle NW	2002 (in press, USGS WPG)
Seattle SE	2004 (map near completion 10/03)
Seattle NE	2004 (map in progress 10/03)



Figure 2. Map quadrangles for the City of Seattle

INVESTIGATIONS AND RESULTS

COMPONENT 1—REGIONAL STRATIGRAPHY AND CHRONOLOGY

We have produced a chronological and lithologic composite section of glacial and nonglacial deposits in the central Puget Lowland that is being used to evaluate the distribution, correlation, and deformation of individual geologic units across the region, based on extensive field and laboratory analyses (e.g., Figure 3). We have produced several significant publications this year based on this work, including a chapter in an upcoming volume on Quaternary geology for the International Quaternary Association (INQUA), a submission to the journal *Geology*, and collaboration on a variety of other studies presented at the GSA annual meeting in Seattle (November 2003). We have established the regional nomenclature, unit descriptions, and updated stratigraphic timescale (Figure 4) that are being used by scientists, local agencies, consultants, and upcoming USGS map products being developed by our group and others. Through collaboration with USGS scientists we have shown that the stratigraphic units identified at type sections on Whidbey Island, north of Seattle, can be mapped in the Tacoma area, and we have newly identified deposits from climatic stages previously undocumented in the Lowland.

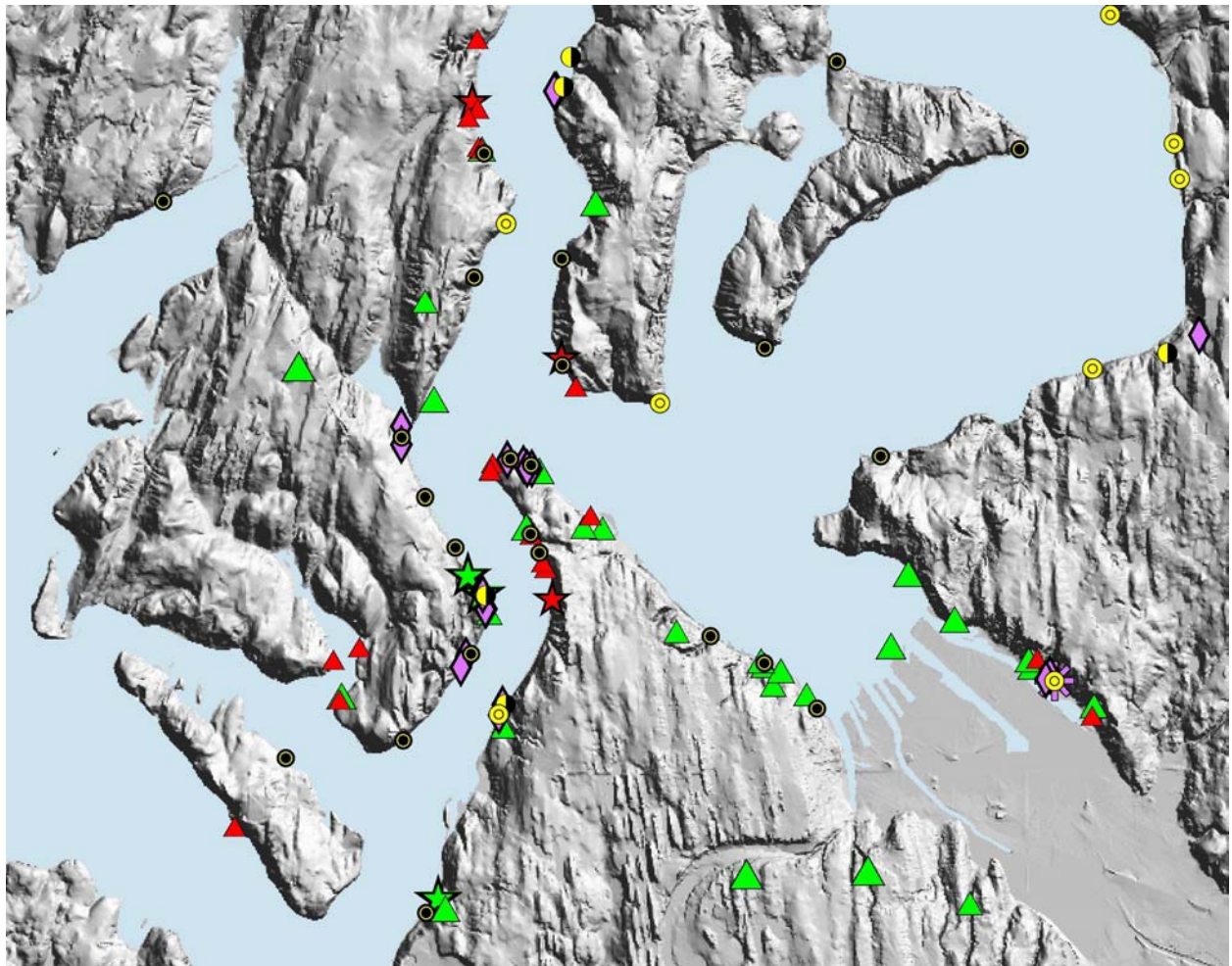


Figure 3. Map of analytic samples of Quaternary sediments collected, dated, and/or compiled by the Seattle-Area Geologic Mapping Project. Key: circles = paleomagnetic samples, diamonds = IRSL age samples, triangles and stars = ^{14}C age samples, snowflake = fission-track age sample

Figure

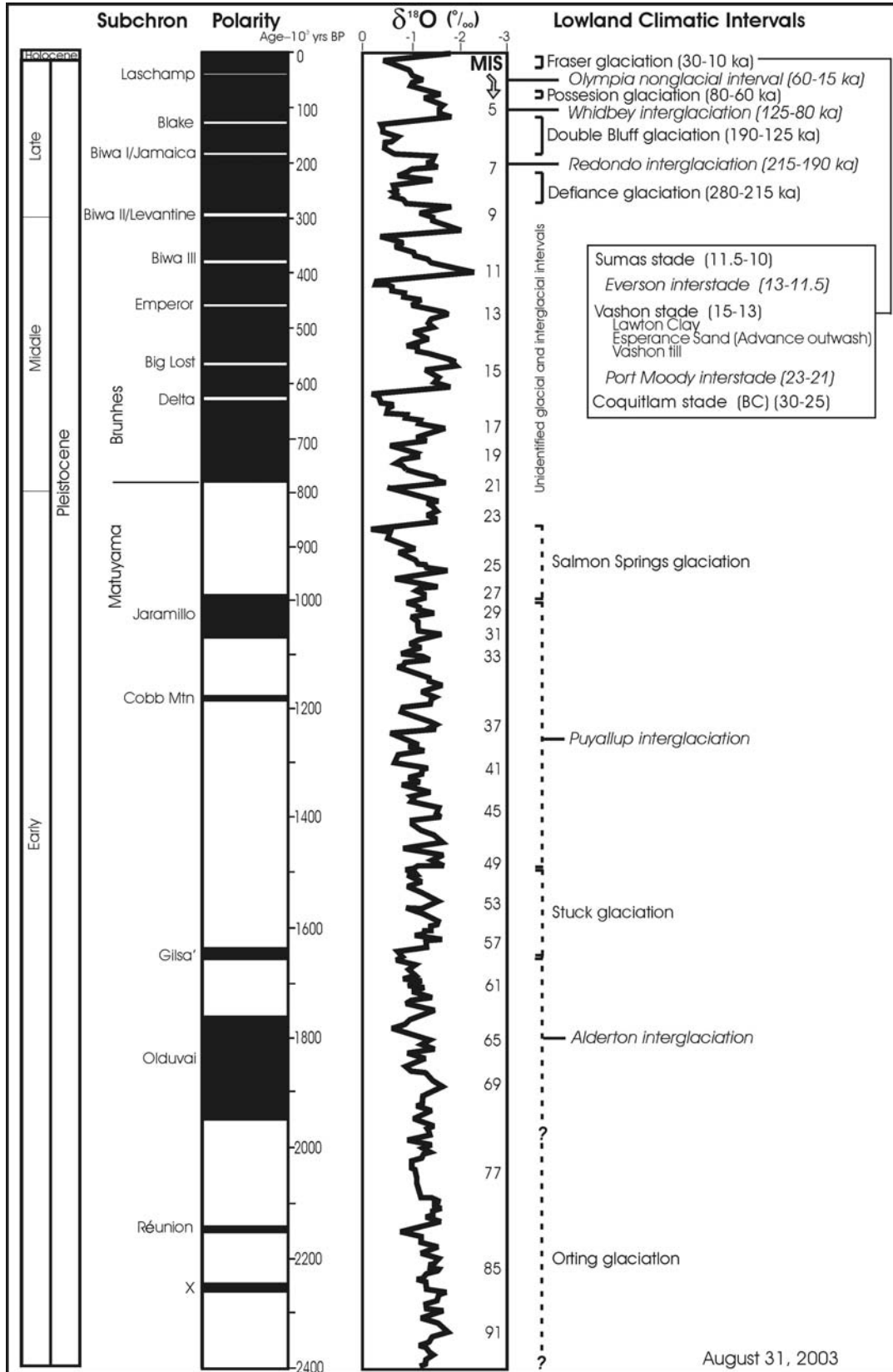


Figure 4. Comparison of the marine oxygen-isotope curve stages (MIS) using the deep-sea oxygen-isotope data, global magnetic polarity curve, and ages of climatic intervals in the Puget and Fraser lowlands (modified from Booth et al., 2003, and original references cited therein). Ages for the Defiance glaciation and Redondo interglaciation are from Troost et al. (2003).

COMPONENT 2—SUBSURFACE GEOLOGIC DATABASE FOR THE CITY OF SEATTLE

We are continuing to add to a comprehensive subsurface geologic database for the City and surrounding regions (Figure 5), funded by a combination of local agencies and USGS NEHRP. The database has been fully designed; its population is up-to-date for data held by the City of Seattle and many of the surrounding cities and contains more than 56,000 individual exploration sites. Within the City of Seattle alone, over 5400 separate geotechnical reports, which include over 30,000 individual exploration sites, have been indexed in an MS Access database and displayed on an ArcView GIS platform. They have been obtained from the City's Department of Design, Construction, and Land Use office (DCLU), submitted from private geotechnical consultants in support of building permit applications; from the in-house soils laboratory of Seattle Public Utilities (SPU); and from the SPU Vault, King County Department of Natural Resources Technical Library, the Washington Department of Ecology, and private consultants. We are continuing to collect and enter data from the City of Seattle.

Our progress through 2003 in populating the main tables of the database is as follows:

	Total area— to date (11/13/03)	Seattle only— to date (11/13/03)
DOCUMENTS	9995	5444
POINTS	56,555	41,000
LAYERS	218,824	117,105



Figure 5. Current areas of coverage; pink highlight indicates the geographic coverage of the geologic database.

COMPONENT 3—SURFICIAL GEOLOGIC MAPS OF THE CITY OF SEATTLE

We have nearly completed new geologic map coverage for the City, based on a combination of field investigations (coastal and river-valley bluffs, excavations, landslide scars) and near-surface borehole data. The Seattle SW and NW quadrangles are through USGS technical review; fieldwork and database entry is complete for the Seattle SE and NE quadrants, although we continue to add to the database for all four quadrangles as new documents are acquired from the City and consultants. As the fully reviewed maps receive USGS Team Approval, they are available for viewing on the project's web site (Figure 6).

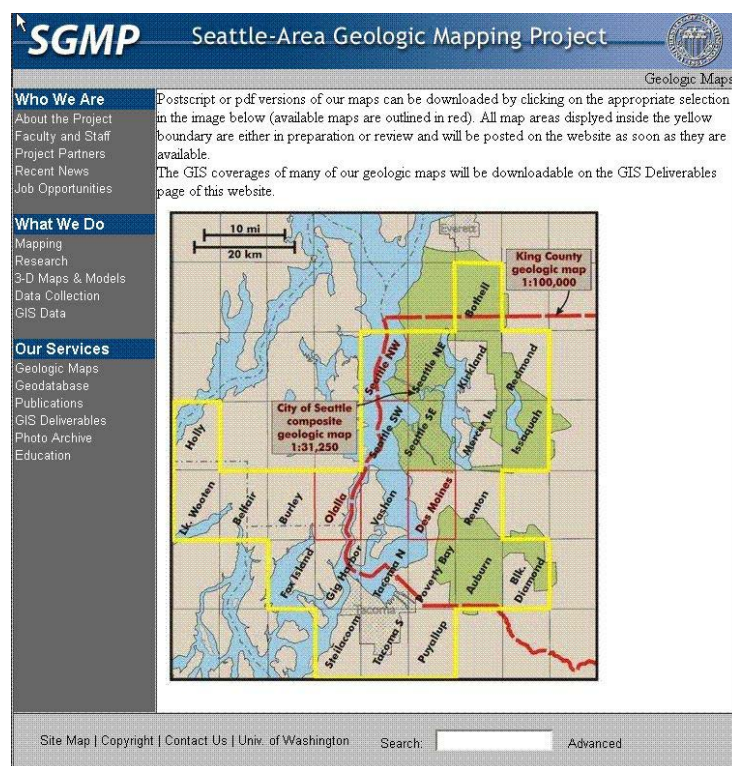


Figure 6. Index-map interface for downloading/viewing geologic maps with completed technical review.

COMPONENT 4—THREE-DIMENSIONAL GEOLOGIC MODEL OF THE CITY OF SEATTLE

Our progress on this component of the project has been significantly slower than anticipated, primarily because the project expertise for its development must be shared with enhancing the Internet presence and database access for the project. We have chosen to accelerate the latter efforts at the expense of 3-D mapping. This is an acknowledgement that our major funding sources have placed a very high priority on public access to the data, a goal that is compatible with the USGS as well, although not part of our original scope. Our work continues on the 3-D effort, however, with a portion of the Seattle NW quadrangle as our prototype area.

Despite the broad spatial distribution of the down-hole data, the limited depths of most borings do not facilitate either automated interpretations of the subsurface geology or spatial interpolation of material properties. Major transit and sewer projects provide excellent but very

widely spaced transects of deep, high-quality borehole data for ground truthing between outcrops. Therefore, we are not modeling the contents of the database directly. We are, however, interpreting each lithologic layer in each borehole by assigning stratigraphic units that can then be mapped individually. The surface maps, in combination with their supporting information from the database, provide an excellent foundation for developing 3-D geologic maps, where the nature and location of subsurface geologic contacts are constrained by borehole interpretations and the known or inferred processes of deposition. We have transferred these data into the software package EVS, where the geologic units in the subsurface can be attributed with the properties of the sediments with which we are familiar from surface exposures and geotechnical data. These 3-D geologic maps can subsequently be exported to construct a subsurface model for use in groundwater, landslide, or ground-shaking applications. Our choice of EVS has been motivated in large part because of its facility in exporting data in a wide variety of formats.

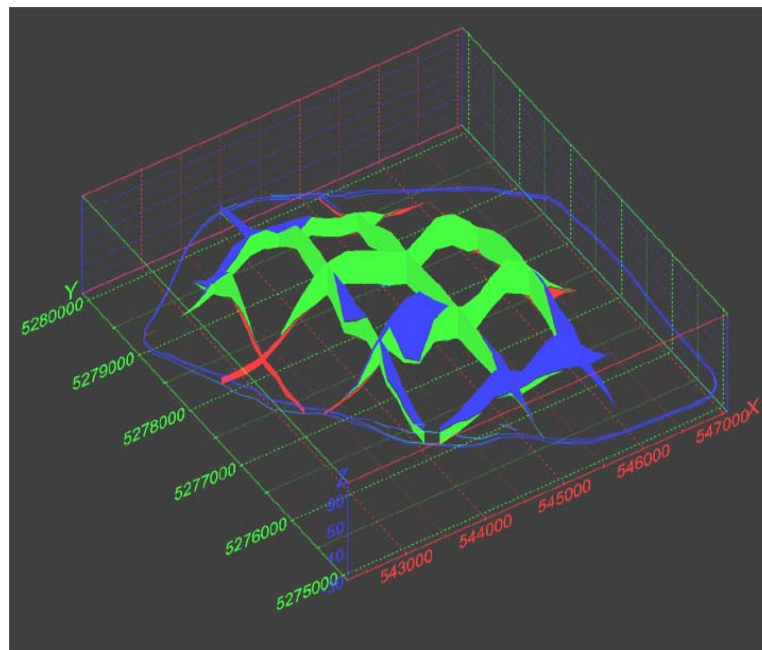


Figure 7. Cross sections at 1000-m spacing displaying the 3-D solid model of Magnolia Hill. North is to the upper right; map boundary of the Seattle NW quadrangle is along the right edge (near UTM coordinate 547000). Blue = glacial till (unit Qvt); green = advance outwash (unit Qva); red = Lawton Clay (unit Qvlc).

COMPONENT 5—EDUCATION AND TECHNICAL OUTREACH

This is an ongoing effort with steadily increasing attention and influence. It is anticipated to continue throughout the duration of the project. Specific activities for this component through the end of 2003 are summarized in the following table:

ACTIVITY	DATE	AUDIENCE
SHORT COURSES—1999 - 2002		
Quaternary Geology of the Central and Southern Puget Lowland (3 days including a 1-day field trip)	April 1999 and Sept 2000	Consultants, Agency Staff, Public
Quaternary Geology of the Central and Southern Puget Lowland	Jan 2000	Nelson Couvrette Associates
Quaternary Geology of the Central and Southern Puget Lowland (2 days including field trip)	May 2000	Landau Associates
Puget Lowland Geologic Framework (1 day)	Oct 2001	King County Wastewater Treatment Division and its consultants
Field classification and geology for drillers	September 2002	Department of Ecology-supported course for well-drilling professionals
Puget Lowland Geologic Framework (1 day)	December 2002	King County Wastewater Treatment Division and its consultants
SHORT COURSES—2003		
Quaternary Geology of the Central and Southern Puget Lowland (3 days including a 1-day field trip)	May 2003	Consultants, Agency Staff, Public
Puget Lowland Geologic Framework (1 day)	January 2003	King County Wastewater Treatment Division and its consultants
FIELD TRIPS—1999 - 2002		
Geology of the Central Puget Lowland	June 1999	Northwest Geological Society
Geology of Seattle	June 1999 and Aug 2000	City of Seattle Staff
Geology of Seattle	Sept 2000	UW Department of Geology and Geophysics
Geology of the Seattle Southwest Quad	July 2000	Technical Advisory Group Members
Quaternary Geology of the Central and Southern Puget Lowland (2-day)	June 2000	Association of Engineering Geologists
Prehistoric Earthquake and Tsunami in the Puget Sound area	Sept 2000	WSSPC attendees: state geologists and

		emergency managers
Geology of Seattle	Oct 2001	Department of Earth and Space Sciences, Univ. of WA alumni
Geology of the Seattle Area	June 2002	Northwest Geological Society
Geology of Seattle	Nov 2002	Department of Earth and Space Sciences, Univ. of WA alumni
FIELD TRIPS—2003		
Geology of Seattle	Oct 2003	City of Seattle staff
Seattle Fault	Oct 2003	Monorail Consultants
Geology of the Seattle Area	Nov 2003	Association of Women Geoscientists
Quaternary Geology of Seattle	Nov 2003	Geological Society of America, Annual Meeting,
TECHNICAL MEETINGS—1999 - 2002		
USGS Workshop on Geologic Hazards in the Puget Lowland	Nov 2000	Emergency Management and Geo/Eng Professionals
Project Updates	Quarterly	City of Seattle departments; King County
Project Updates	Quarterly, plus more frequent as needed	City of Seattle departments; King County
ANSS Advisory Committee (Siting sub-committee)	Quarterly, appx.	USGS, consultants, state
Technical Advisory Group Meetings	Semi-annual	TAG Members
TECHNICAL MEETINGS—2003		
Seattle Geology	March 2003	Seattle Emergency Management, city staff
Workshop on Geologic Research in the Seattle Area	October 2003	Seattle Monorail Project; USGS; Washington Dept. of Natural Resources
Technical Advisory Group Meetings	Semi-annual	TAG Members
Archiving and Dissemination of Geotechnical Data; COSMOS/PEER-Lifelines Project 2L02	Semi-annual	CalTrans, CEC, PG&E, PEER, USGS, CGS,

		UCB, USC, and others
CONFERENCES—1999 - 2002		
Co-convenor of the Seattle Urban Geologic Hazards Workshop	February 1999	ca. 200 agency staff and private consultants
Evening Forum on the Quaternary Geology of the Puget Lowland	August 1998; October 2000	2 nd and 3 rd Symposia on the Hydrogeology of Washington State
Geology of Seattle at the Seismological Society of America's Annual Meeting public forum	April 1999	SSA attendees and general public
Many individual presentations	ongoing	Professionals and research community
Convened a 1.5-day symposium on the Quaternary Geology of the Puget Lowland	April 2000	GSA attendees
Nisqually Earthquake symposium Seismological Society of America's Annual Meeting	April 2001	SSA attendees and general public
GSA North-Central Section Meeting Special Workshop on 3-D Mapping and Groundwater Modeling	April 2001	GSA Attendees
National Association of Geology Teachers, Western Division Meeting	June 2001	NAGT attendees and professionals
Convened symposium on the geology of glaciated regions at Geological Society of America annual meeting	November 2001	GSA attendees
Symposium on the Nisqually earthquake	April 2002	Annual meeting, Seismological Society of America
Symposia on the Quaternary Geology of the Puget Lowland and the Nisqually Earthquake (co-convenors and presenters)	April 2002	GSA Cordilleran Section meeting
3-D mapping workshop	October 2002	GSA Annual Meeting
CONFERENCES—2003		
Symposium on the Quaternary Geology of the Puget Lowland (co-convenors and presenters)	November 2003	GSA Annual Meeting
Hosted an exhibit booth at GSA national meeting in Seattle	November 2003	GSA Annual Meeting
PUBLIC MEETINGS AND SELECTED INVITED TALKS—1999 - 2002		
Co-convenor, Urban Seismic Hazards Mapping Project Workshop	February 1999	USGS, UW, local agencies, public
Project Impact Disaster Saturdays: Display of "The Geology of Seattle" complete w/geologic samples and stratigraphic models	All, 1999, 2000, and 2001	Public
Ground Failures from the Nisqually Earthquake and	Multiple	CPARM; emerg.

the Geology of Seattle	presentations	managers; Univ. Puget Sound, K-12 classes
Mapping the Geology of Seattle	February 2001	Assoc. of Women in Science; Assoc. for Women Geoscientists
NOAA Tsunami Workshop	February 2001	Emergency managers
Invited presentations at Seismological Society of America annual meeting and Geological Society of America Cordilleran section meeting	April 2002	SSA, GSA
Brown-bag presentations on Seattle-area geology to local consulting firms	June 2002, September 2002	GeoEngineers; Landau and Associates
The Seattle-Area Geologic Mapping Project	October 2002	Local chapters, Association of Engineering Geologists & American Society of Civil Engineers
PUBLIC MEETINGS AND SELECTED INVITED TALKS—2003		
Geology and Rivers	March 2003	Center for Water and Watershed Studies seminar series, University of Washington
Geology and Rivers in the Puget Lowland	June 2003	American Water Resources Association, monthly chapter meeting
Faults Beneath our Feet (moderator/host)	November 2003	Geological Society of America Public Forum

Local Agency and Public Outreach. Because of the potential utility of the geologic map products, and because of the efforts being invested by this project on behalf of geologic studies by *all* scientists throughout the region, we have received unprecedented support from local governments. The value of these efforts has been directly articulated and is more substantively demonstrated by the successful leveraging of USGS NEHRP funds (see *Financial Notes* section, below).

The geologic and engineering consultants of the region recognize our leadership in defining the stratigraphy, lithology, and geologic history of this area. They frequently solicit our opinions regarding various specific sites, and they utilize our database and our mapping efforts in their own investigations, which we provide in exchange for additional data. They also now utilize the nomenclature and color scheme for the region that we have established through this project.

City of Seattle and King County Wastewater Treatment Division employees and their consultants are using our database and map products at their desktops. In addition, anyone with an internet provider can access downhole data from our website.

Technical Advisory Group (TAG). A TAG was established early in our first year to enhance communication between this project and the end users of the products, consultants and agency representatives. Its membership (53 counting Troost and Booth) emphasizes senior members of the region's geologic, geotechnical, hydrogeologic, and engineering consulting firms; and representatives from state, city, and local agencies who will be both the major users and the major contributors:

Consulting Firms

AMEC
Aspect Consulting LLC
Associated Earth Sciences
Boeing Aerospace Company
Cascade Drilling
CDM Jessberger
Environmental Partners
R. Free Consulting
Galster Consulting
GeoEngineers, Inc.
Golder Associates, Inc.
Hart Crowser
Herrera Consultants
HWA Geosciences
Landau Associates
Nelson Geotechnical
Robinson & Noble, Inc.
Roth Consulting
SCS Engineers
Shannon & Wilson, Inc.
Terra Associates
Tubbs Geosciences
Udaloy Environmental Services
URS Corporation
Yonemitsu Geological Services

Agencies

City of Seattle – Design, Construction, and
Land Use; Seattle Public Utilities; Parks
Department
City of Tacoma
Island County Health Department
King County Department of Natural
Resources
King County Wastewater Treatment Div
King County DDES
US Army Corps of Engineers
US EPA
USGS – Water Resources & Geologic
Divisions
University of Washington
WA Dept. Nat.l Res., Div. Of Geology &
Earth Res. & BSSD
Washington Department of Ecology
Washington Dept of Transportation

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Many engineering applications in urban and urbanizing areas depend on the spatial distribution of geologic materials and the sequence and history of their deposition. This project is developing a detailed understanding and representation of the three-dimensional distribution of geologic materials beneath Seattle and the surrounding urban, and urbanizing, region. To date, we have acquired and organized over 55,000 items of geologic information, representing a substantial start on of the vast amount of existing data; in combination with our ongoing field investigations, we are preparing and publishing the geologic maps to display this information for scientists, agencies, and the public.

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1998-2002

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GEOLOGIC MAPS—current status (11/03):

In preparation

- Troost, K. G., Booth, D. B., and S. Shimel, in review, Geologic map of the Seattle SE quadrangle: U.S. Geological Survey Miscellaneous Investigations Map, scale 1:12,000.
- Booth, D. B., Troost, K. G., and S. Shimel, in press, Geologic map of the Seattle NE quadrangle: U.S. Geological Survey Miscellaneous Investigations Map, scale 1:12,000.
- Booth, D. B., Troost, K. G., and S. Shimel, in press, Geologic map of the Issaquah quadrangle: U.S. Geological Survey Miscellaneous Investigations Map, scale 1:24,000.

In review

- Troost, K. G., in review, Geologic map of the Puyallup 7.5-minute quadrangle, Washington: U.S. Geological Survey Miscellaneous Investigations Map, scale 1:24,000.

- Troost, K. G., in review, Geologic map of the Tacoma South 7.5-minute quadrangle, Washington: U.S. Geological Survey Miscellaneous Investigations Map, scale 1:24,000.
- Troost, K. G. and Booth, D. B., in review, Geologic map of the Steilacoom 7.5-minute quadrangle, Washington: U.S. Geological Survey Miscellaneous Investigations Map, scale 1:24,000.
- Troost, K. G., Booth, D. B., and R. Borden, in review, Geologic map of the Tacoma North 7.5-minute quadrangle, Washington: U.S. Geological Survey Miscellaneous Investigations Map, scale 1:24,000.
- Troost, K. G., Booth, D. B., and R. Wells, in review, Geologic map of the Gig Harbor 7.5-minute quadrangle, Washington: U.S. Geological Survey Miscellaneous Investigations Map, scale 1:24,000.
- Troost, K. G., Booth, D. B., and S. Shimel, in review, Geologic map of the Seattle SW quadrangle: U.S. Geological Survey Miscellaneous Investigations Map, scale 1:12,000.

In press

- Booth, D. B., and Troost, K. G., in press, Geologic map of the Olalla 7.5-minute quadrangle, Washington: U.S. Geological Survey Miscellaneous Field Investigation, scale 1:24,000.
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- Booth, D. B., H. H. Waldron, and Troost, K. G., in press, Geologic map of the Poverty Bay 7.5-minute quadrangle, Washington: U.S. Geological Survey Miscellaneous Field Investigation, scale 1:24,000.
- Booth, D. B., R. A. Haugerud, and J. Sacket, in press, Geologic map of King County, Washington: U.S. Geological Survey Open-File Report, scale 1:100,000.

FINANCIAL NOTES

This project has been quite successful in leveraging the contribution of the USGS NEHRP funds through additional financial and in-kind support from other programs of the USGS and from local governments. Some of that support has been used to cover the initial shortfall of funds for the originally scoped NEHRP project (namely, the geologic map of the City of Seattle), some has been used to develop the scientific framework for Quaternary geologic investigations in the region (Component 1 of this project), and some has been used to expand the geographic scope of the effort into populated areas to the north, south, and east. Funding amounts are tabulated and also shown graphically below:

Project Funding 2000-2003:

DIRECT FUNDING

SOURCE	2000	2001	2002	2003
USGS: NEHRP	\$160,000	\$170,000	\$170,000	\$125,000
USGS: NCGMP	\$38,332	\$12,450	\$31,617	\$36,975
City of Seattle: DCLU	\$60,000	\$60,000	\$60,000	\$60,000
City of Seattle: SPU	\$50,000	\$25,000	\$25,000	\$25,000
Univ. of WA: CUWRM	\$20,000	\$10,000	\$10,000	\$10,000
King Co. Wastewater		\$327,449	\$216,600	\$278,420
City of Bothell			\$15,000	\$0
KC Groundwater project			\$25,000	\$0
	\$328,332	\$604,899	\$553,217	\$535,395

